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EXAMINATION OF AIR QUALITY ASSOCIATED WITH AGRICULTURAL STUBBLE BURNING SEPTEMBER - OCTOBER, 1987

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ABSTRACT

In response to public concern regarding the effects of smoke produced from agricultural stubble burning, a study was undertaken to monitor particulate levels, polynuclear aromatic hydrocarbons (PAH), and volatile organic compounds (VOC) during smoke events in the vicinity of Winnipeg.

Elevated levels of both total and inhalable particulate were observed during known smoke events in the Winnipeg area. In one case, total suspended particulate levels were found to exceed the Maximum Accetable level of 120 $\mu g/m^3$ as set out in the Manitoba Air Quality Objectives.

Elevated levels of a number of PAH compounds and aromatic compounds were observed in comparison to background during known incidents of agricultural burning.

TABLE OF CONTENTS

	PAGE
ABSTRACT	i
TABLE OF CONTENTS	ii
LIST OF TABLES AND FIGURES	iii
BACKGROUND	1
MANITOBA AIR QUALITY OBJECTIVES AND GUIDELINES	4
PROCEDURES	6
MONITORING SITES	8
RESULTS	9
DISCUSSION	16
CONCLUSIONS	24
ACKNOWLEDGEMENTS	25
REFERENCES	26
APPENDICES	28

LIST OF TABLES AND FIGURES

TABLES		PAGE
1	Manitoba Air Quality Objectives and Guidelines for Total Suspended Particulates.....	5
2	VOC Concentrations Site 2031, Winnipeg.....	11
3	PAH Concentrations Station 2031, Winnipeg.....	13
4	Particulate Concentration, Station 2031, Winnipeg...	14
5	Meteorological Data, Station 2031, Winnipeg.....	15
6	Province of Ontario, 24 Hour Guidelines and Standards	20
7	Comparison of Selected VOC Concentrations.....	21

BACKGROUND

Public concern has been raised regarding the effects of smoke produced from the burning of agricultural residues such as stubble. These events usually occur in the fall, at the end of the growing season, after harvesting has been completed. These incidents routinely produce large amounts of smoke, obscuring visibility on highways, and in urban areas, leading on occasion to hazardous driving conditions. Potential health effects have also been reported, especially among individuals suffering from respiratory disorders.

Little literature has been published regarding the combustion products produced as a result of agricultural burning. The information contained in this report is intended to provide preliminary data from surveys conducted during smoke incidents.

To attempt to characterize emissions from this source, three types of parameters were examined in this study:

1) Particulate levels - Total and Inhalable
2) Polynuclear Aromatic Hydrocarbons
3) Volatile Organic Compounds

Total suspended particulate (TSP), is defined as particles in the solid or liquid phase which exist in a size and configuration which allows them to remain suspended in ambient air. Major contributors to TSP levels within urban centres are emissions from industrial plants, secondary particulate formation (smog) and entrainment of dust from agricultural areas during high wind conditions. Forest fires and other major combustion sources have also been found to contribute significantly to elevated TSP levels.

Inhalable particulate (IH) may be defined as solid or liquid particles which not only may remain suspended in air, but also are of a size which allows them to penetrate into the tracheobronchial and alveolor regions of the lung in a living organism, causing distress and contributing to respiratory disorders. Studies have established that particles with an aerodynamic diameter of less than 10 microns are susceptible to this process (1).

Polynuclear aromatic hydrocarbons (PAH) are a class of compounds in which single aromatic rings have been fused into chains of various configurations. More than 250 of these compounds have been characterized, according to recent literature (2). PAH compounds are routinely produced as a result of incomplete or low temperature combustion, and have been found to constitute a significant component of both particulate and gaseous smoke emissions. Particulate PAH compounds are primarily in the respirable range (<10 microns).

Evidence presented by various researchers is indicative that certain polynuclear aromatic hydrocarbons are toxic, and represent priority pollutants (3, 4, 5, 6, 7). Some of these compounds have been implicated as carcinogens, co-carcinogens, or respiratory irritants.

Volatile organic compounds (VOC) is a term used for monitoring to identify and quantify selected organic compounds in the alkane, aromatic, alkyl halide and halogenated aromatic categories.

Monitoring has been undertaken by Environment Canada (8) to identify ambient levels of these compounds, and to quantify industrial point sources of emission. A number of the VOC compounds examined in this study have known or suspected carcinogenic properties.

The following objectives were defined for this study:

1) To determine levels of ambient particulate, both total and inhalable, during known smoke events in the vicinity of Winnipeg.
2) To examine PAH emissions during events of this nature, to determine if elevated concentrations of these compounds are observed.
3) To measure ambient VOC levels in the area during smoke episodes, to determine ambient levels of these compounds.

MANITOBA AIR QUALITY OBJECTIVES AND GUIDELINES

The Manitoba Government has adopted criteria for various air pollutants. These criteria are known as the Manitoba Air Quality Objectives and Guidelines (Environmental Management Division, 1985). The maximum levels of total suspended particulate are presented in Table 1. The establishment of objectives and guidelines are based upon three assessment levels:

1. Maximum Tolerable Level (M.T.L.)

   This level denotes a time-based concentration of air contaminant beyond which, due to a diminishing margin of safety, appropriate action is required to protect the health of the general population.

2. Maximum Acceptable Level (M.A.L)

   This level is deemed essential to provide adequate protection for soils, water, vegetation, materials, animals, visibility, personal comfort, and well-being.

3. Maximum Desirable Level (M.D.L.)

   This level defines the long term goal for air quality and provides a basis for an anti-degradation policy for the pristine areas of Manitoba and for the continuing development of control technology. At this level, there would be no adverse biological effect on any receptor.

TABLE 1

MANITOBA AIR QUALITY OBJECTIVES AND GUIDELINES FOR TOTAL SUSPENDED PARTICULATE

Contaminant	Time Period Measured	Max. Tolerable Level ($\mu g/m^3$)	Max. Acceptable Level ($\mu g/m^3$)	Max. Desirable Level ($\mu g/m^3$)
Total Suspended Particulate	24 hour Average	400	120	*
	Annual Geometric Mean	*	70	60

* No objective or guideline set

PROCEDURES

A) VOLATILE ORGANIC COMPOUNDS (VOC)

Sampling was performed using equipment and analytical facilities provided by the Pollution Measurement Division of Environment Canada, in Ottawa. The methods used were those implemented for studies of VOC concentrations in Toronto and Montreal (9). Stainless steel sampling cartridges, 320 mm long, and 15 mm in diameter containing approximately 9 grams Tenax-GC resin (35/60 mesh), were used to trap the organic compounds. A glass fibre filter was used to remove particulate matter. The Tenax adsorbent was pre-cleaned by extracting overnight with two solvents (methanol and pentane). After vacuum drying at 170°C for 15 hours, the sorbent was loaded into the cartridges, which were then conditioned with helium for 8 hours at 300 °C. The conditioned cartridges were cooled to room temperature under continued helium flow, and sealed with stainless steel caps, for shipping to the sampling site.

Ambient air was drawn through the cartridges, using a Metrex model SAS-8 sequential air sampling system, at a rate of 200 cc/min., with total sampling volumes ranging between 180 and 270 litres. After sampling, cartridges were capped and returned to the River Roads Environmental Technology Centre in Ottawa, for analysis.

Samples were thermally desorbed from the exposed cartridges, by heating and purging with helium, and preconcentrated into a liquid nitrogen cooled trap. The trapped organics were flash heated, and analyzed using gas chromatography. Analysis was performed for 55 organic compounds.

B) POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)

Sampling for polynuclear aromatic hydrocarbons was undertaken using a modified high volume air sampler method, developed by Environment Canada (10). Compounds were adsorbed on cartridges containing plugs of polyurethane foam, which had been Soxhlet extracted for 24 hours using methanol and cyclohexane. The cleaned PUF plugs are loaded into glass tubes, which in turn are loaded into aluminum canisters, with teflon gaskets, spacers and end caps. Aluminum cap rings are used to seal the canister assembly, which is then ready for shippping to the field site. A preweighed, teflon coated glass fibre prefilter is used in the sampling train, to trap particulate.

Ambient air is drawn through the filter/canister assembly, using the modified high volume air sampler. The sampler operates at a flowrate of 600 to 700 litres per minute. Total air sample volumes for the study ranged between 640 and 1040 cubic meters. After sampling cartridges and filters were sent to the River Roads Environmental Technology Centre in Ottawa for analysis.

The exposed filters and PUF plugs were Soxhlet extracted, and analyzed using a gas chromatography/mass spectroscopy system. Analysis was performed for 27 compounds; however, 26 individual results are reported, as some of the compounds are unresolved on the analytical column used (see Appendix A for compound properties and structures).

C) TOTAL SUSPENDED PARTICULATE (TSP)

Sampling for TSP was conducted using a standard high volume particulate sampler equipped with glass fibre filters. This sampling methodology is consistent with the standard reference method developed by Environment Canada (9).

Glass fibre filters, pre-weighed at the W. M. Ward Technical Services Laboratory, were used as sampling media to trap particulate suspended in air. Samples were analyzed using standard gravimetric techniques for particulate.

D) INHALABLE PARTICULATE

A modified high volume air sampler equipped with an Anderson Model 7000 size selective particulate sampling head was used for measurement of inhalable particulate. This system uses the principle of cascade impaction to separate respirable particulate with a cut off size of 10 micrometers.

Samples were collected on preweighed glass fibre filters using standard high volume air sampling procedures. Samples were submitted to the W. M. Ward Technical Services Laboratory for gravimetric particulate analysis. Results were reported as concentrations of mass per unit volume of air.

MONITORING SITES

Samples were collected at a site, designated 2031, located at 500 Shaftsbury Boulevard, Winnipeg. This site was located on the grounds of the Manitoba School for the Deaf, in a residential area

approximately 8 kilometers southwest of the city centre (see map 1, Appendix B). The intakes for the samplers were located 5 metres above ground level. The nearest major streets were located approximately 200 metres east and 600 metres south of the site. The nearest industrial area is located approximately 5 kilometres southeast of the site.

Siting was determined on the basis of meteorological data taken during known incidents of smoke attributed to agricultural burning in the vicinity of Winnipeg. Prevailing wind direction during these incidents was found to vary between 180 and 300 degrees, corresponding with neighbouring areas of high flax production. These crops continue to be burned if the straw cannot be baled and sold for the fibre processing industry. As it was difficult to predict when burning would occur, the location was chosen with the intent of providing the highest probability of impingement during an incident, within the siting criteria.

RESULTS

Five samples were collected for both VOC and PAH compounds. The samples were analyzed for 55 VOC and 27 PAH compounds, and results are listed in Tables 2 and 3, respectively. VOC data is reported in units of micrograms per cubic metre, while PAH is shown in units of nanograms per cubic metre (ng/m^3), both corrected to 25°C and 1 atmosphere of pressure.

Sixteen samples were collected for both total and inhalable particulate during the course of the study. Results are listed in

Table 4, and are reported in units of micrograms per cubic metre of air ($\mu g/m^3$), corrected to 25°C and 1 atmosphere of pressure.

A summary of meteorological conditions which were observed on-site during the monitoring period is given in Table 5.

TABLE 2
VOC CONCENTRATIONS ($\mu g/m^3$)
SITE 2031 - WINNIPEG

COMPOUNDS	DATE				
	21-SE-87	25-SE-87	28-SE-87	14-OC-87	22-OC-87
PENTANE	2.42	9.23	14.28	2.78	0.00
ISOPRENE	0.00	0.53	0.21	0.21	0.15
trans-2-PENTENE	0.31	1.31	0.55	0.00	0.13
cis-2-PENTENE	0.15	0.70	0.19	0.38	0.08
2-METHYL-2-BUTENE	0.49	1.97	0.43	0.60	0.22
2,2-DIMETHYLBUTANE	0.07	0.12	0.11	0.02	0.15
CYCLOPENTANE	0.33	1.62	0.33	19.48	0.56
2,3-DIMETHYLBUTANE	0.36	1.28	0.61	0.00	0.00
2-METHYLPENTANE	1.80	9.64	2.22	11.81	2.24
3-METHYLPENTANE	9.68	3.89	1.42	0.81	1.28
HEXANE	1.12	5.30	8.48	8.36	1.50
METHYLCYCLOPENTANE	1.06	5.27	1.52	8.77	0.88
2, 4-DIMETHYLPENTANE	0.47	2.04	0.38	3.35	0.39
BENZENE	2.29	8.18	2.21	16.19	1.74
CYCLOHEXANE	0.30	0.83	0.85	2.72	0.24
2-METHYLHEXANE	0.72	3.12	0.63	7.74	0.84
2, 3-DIMETHYLPENTANE	1.96	3.98	0.69	6.47	0.85
3-METHYLHEXANE	0.89	3.64	0.68	6.03	0.80
2, 2, 4-TRIMETHYLPENTANE	1.27	4.53	1.02	6.24	0.94
HEPTANE	0.86	3.12	0.67	2.66	0.65
METHYLCYCLOHEXANE	1.10	2.44	0.28	1.59	0.30
2, 4-DIMETHYLPENTANE	0.33	1.12	0.24	0.63	0.29
2, 3, 4-TRIMETHYLPENTANE	0.38	1.23	0.25	0.00	0.26
TOLUENE	5.44	18.11	4.27	31.56	4.77
2-METHYLHEPTANE	0.62	1.34	0.23	3.43	0.31
3-METHYLHEPTANE	0.07	0.58	0.25	2.91	0.35
OCTANE	0.14	2.95	0.49	2.81	0.63
ETHYLBENZENE	1.20	3.73	0.82	8.01	0.94
m-, p-XYLENE	6.54	17.77	3.69	35.88	4.48
STYRENE	0.58	0.81	0.28	2.37	0.61
o-XYLENE	2.71	7.28	1.46	14.77	1.96
n-NONANE	0.98	2.80	0.33	0.34	0.58
ISOPROPYLBENZENE	0.62	0.50	0.46	1.07	0.24
n-PROPYLBENZENE	0.72	1.97	0.49	3.55	0.47
3-METHYLTOLUENE	2.34	5.20	1.12	10.53	1.20
2-METHYLTOLUENE	1.53	2.48	0.45	3.67	0.52
1, 3, 5-TRIMETHYLBENZENE	2.42	3.83	0.64	0.68	0.85
4-METHYLTOLUENE	0.81	1.84	0.34	3.61	0.48
1, 2, 4-TRIMETHYLBENZENE	4.10	8.53	1.58	18.07	2.34
DECANE	3.42	3.12	1.04	3.31	0.90
ISOBUTYLBENZENE	0.79	0.66	0.10	0.88	0.10
p-CYMENE	2.36	3.29	0.67	5.45	0.77
1, 2, 3-TRIMETHYLBENZENE	0.85	1.21	0.49	0.76	0.33
DICHLOROMETHANE	5.83	6.68	5.68	5.10	1.86
CHLOROFORM	0.28	0.63	0.23	0.63	0.23

TABLE 2 continued
VOC CONCENTRATIONS ($\mu g/m^3$)
SITE 2031 - WINNIPEG

COMPOUNDS	DATE				
	21-SE-87	25-SE-87	28-SE-87	14-OC-87	22-OC-87
1, 1, 1-TRICHLOROETHANE	2.70	3.08	1.78	3.69	4.41
CARBON TETRACHLORIDE	2.43	2.12	0.88	0.79	1.11
TRICHLOROETHYLENE	0.20	0.27	0.43	1.94	0.20
1, 1, 2-TRICHLOROETHANE	0.03	0.02	0.00	0.00	0.02
ETHYLENE DIBROMIDE	0.01	0.02	0.01	0.00	0.01
TETRACHLOROETHYLENE	0.64	1.05	0.62	1.85	1.44
CHLOROBENZENE	0.18	0.10	0.00	0.00	0.00
1, 3-DICHLOROBENZENE	0.07	0.12	0.00	0.00	0.00
1, 4-DICHLOROBENZENE	0.54	0.74	0.21	0.33	0.16
1, 2-DICHLOROBENZENE	0.04	0.10	0.00	0.02	0.02

TABLE 3
PAH CONCENTRATIONS (ng/m^3)
STATION 2031 - WINNIPEG

COMPOUNDS	DATE				
	13-SE-87	21-SE-87	28-SE-87	14-OC-87	22-OC-87
ACENAPHTHYLENE	0.71	1.72	0.82	25.94	2.97
ACENAPHTHENE	0.44	0.77	0.24	3.79	0.69
FLUORENE	2.28	8.97	1.14	9.04	3.08
2-METHYL-FLUORENE	4.49	6.10	1.98	12.55	4.58
PHENANTHRENE	12.37	7.35	4.22	17.91	8.28
ANTHRACENE	2.04	0.22	0.67	4.81	1.26
FLUORANTHENE	2.26	1.33	0.97	5.10	2.03
PYRENE	1.95	1.19	0.94	5.73	1.95
BENZO(a)FLUORENE	0.42	0.22	0.20	1.17	0.32
BENZO(b)FLUORENE	0.22	0.14	0.11	0.83	0.17
3-METHYL-PYRENE	0.23	0.16	0.11	0.64	0.16
BENZO(g,h,i)FLUORANTHENE	0.28	0.22	0.14	2.08	0.33
BENZO(a)ANTHRACENE	0.32	0.11	0.10	1.47	0.14
CHRYSENE & TRIPHENYLENE	0.20	0.20	0.22	1.81	0.29
2-METHYL-BENZO(a)ANTHRACENE				0.02	
BENZO(b)FLUORANTHENE	0.61	0.71	0.33	3.93	0.43
BENZO(k)FLUORANTHENE	0.20				0.23
BENZO(e)PYRENE	0.20	0.23	0.13	1.45	0.29
BENZO(a)PYRENE	0.10	0.09	0.06	1.31	0.14
PERYLENE	0.01			0.18	0.02
METHYL-CHOLANTHRENE					
o-PHENYLENE	0.30	0.31	0.12	1.90	0.43
DIBENZO-(a,c)&(a,h)ANTHRACENE		0.03	0.02	0.16	0.03
BENZO(b)CHRYSENE				0.09	0.02
BENZO(g,h,i)PERYLENE		0.32	0.15	3.13	0.53
ANTHANTHRENE					
TOTAL PAH	29.78	25.39	12.64	105.03	28.35
TSP (µg/m3)	62.2	42.5	12.5	57.9	30.0

TABLE 4
PARTICULATE CONCENTRATION
STATION 2031 - WINNIPEG

DATE	TOTAL PARTICULATE $\mu g/m^3$	INHALABLE PARTICULATE $\mu g/m^3$	IH / TSP RATIO
Sept. 1/87	48.9	24.2	0.49
Sept. 2/87	101.3	49.8	0.49
Sept. 3/87	96.1	46.7	0.49
Sept. 4/87	32.4	22.4	0.69
Sept. 5/87	90.5	52.8	0.58
Sept. 7/87	130.6	97.3	0.75
Sept. 8/87	53.3	23.7	0.45
Sept. 13/87	61.4	30.1	0.49
Sept. 15/87	47.2	23.1	0.49
Sept. 16/87	47.4	22.8	0.48
Sept. 17/87	9.7	4.8	0.49
Sept. 21/87	39.4	25.7	0.65
Sept. 22/87	70.1	34.2	0.49
Sept. 28/87	10.2	4.9	0.48
Oct. 14/87	52.1	24.4	0.46
Oct. 22/87	26.7	11.5	0.43

TABLE 5
METEOROLOGICAL DATA
STATION 2031 - WINNIPEG

DATE	AVERAGE WIND SPEED (KM/HR)	PREVAILING WIND DIRECTION (DEGREES)	MEAN TEMPERATURE (°C)	COMMENTS
September 1	20	261	15	smoke
September 2	28	173	11	smoke
September 3	10	193	19	smoke
September 4	11	320	16	smoke
September 5	10	151	14	smoke
September 7	9	208	10	smoke
September 8	8	278	10	smoke
September 13	14	184	12	smoke
September 15	12	101	17	smoke
September 16	10	139	17	smoke
September 17	7	283	14	
September 21	7	229	12	odour
September 25	calm	22	10	smoke
September 28	14	300	9	
October 14	14	282	4	smoke
October 22	7	209	0	smoke

DISCUSSION

Smoke incidents from agricultural burning normally occur in the evening hours during late summer and early fall, after harvest has been completed. Severe smoke episodes may be characterized by the presence of a strong "smokey" odour in the affected area, coupled with obscured visibility. In some cases, only the strong odour may be noted.

This phenomenon is observed as a result of two factors related to meteorological conditions. First, most burning is initiated during periods of calm wind conditions, to allow fires to be controlled. Little turbulence in generated, and smoke constituents are not allowed to dilute or dissipate. Surface inversion conditions are prevalent during this time of the year, and are facilitated by the presence of warm air masses from the agricultural burning. Combustion products produced from the fires are held close to the ground by the inversion, and travel in the prevailing wind direction. Both conditions contribute directly to observed smoke incidents.

Little literature has been published regarding the potential health hazards associated with smoke from agricultural burning. It is known that people suffering from respiratory disorders such as asthma have complained of severe discomfort during these episodes. A number of accidents, mostly in rural areas, have also occurred during smoke events. Some have involved fatalities.

Most burning in the vicinity of Winnipeg is found to originate in areas to the northwest and southwest of the city. Cultivation of cereal grains and flax predominate in these areas. A

partial survey conducted by the Manitoba Department of Agriculture in 1987 (11) estimated that 35% of the total fields in these areas were being burned, with most of the burning performed on flax crops. This practice is prevalent with flax straw, if it cannot be sold for use in the fibre processing industries, as it is extremely tough, and does not decompose readily. Burning of cereal grain residues normally increases when crops are heavy, and in late, wet autumns when harvesting is difficult for the farmer.

Mild spring conditions, coupled with abundant rain caused extremely early harvests to occur in the vicinity of Winnipeg in 1987. In some cases, crops had been removed from the fields in late July, with agricultural burning initiated in early August. Four severe incidents were observed, during the evenings of August 12-13 and 26-27, when a number of complaints were received by the Air Pollution Control Section of the Environmental Management Division. These events involved highly obscured visibility in the Winnipeg area, with accompanying odours associated with smoke. Winds were light, varying between northwesterly and southwesterly directions. At this time, project monitors had not been set up. However, total suspended particulate levels recorded at one NAPS site (65 Ellen St. - 70119) were found to exceed the Maximum Acceptable Level of 120 $\mu g/m^3$, averaged over a 24 hour period, on two occasions (August 26 - 121 $\mu g/m^3$, August 27 - 148 $\mu g/m^3$).

Sampling for ambient particulate levels commenced at site 2031 on September 1, 1987. Sixteen samples were taken for TSP and Inhalable Particulate between September 1 and October 22. Due to equipment commitments, samplers for PAH and VOC compounds were not

available from Environment Canada until the second week in September, and were not operational until September 13. Four samples were taken for both PAH and VOC compounds between September 13 and October 22, 1987. Background samples were taken for all parameters on September 28, 1987, when no burning was noted from meteorological sources, complaints received by the Air Pollution Control Section, or local observation.

During the period of study, agricultural burning and related smoke events were noted in the Winnipeg area on most of the sampling days (no smoke was observed on September 17), with varying degrees of severity.

Total suspended particulate levels were found to exceed the 24 hour Maximum Acceptable Limit of 120 $\mu g/m^3$ on one occasion (Sept. 7/88 - 131 $\mu g/m^3$. Background levels taken on September 28 were 10 $\mu g/m^3$. Mean TSP levels observed at a Winnipeg NAPS station with a similar profile (299 Scotia St.) average at approximately 30 $\mu g/m^3$, based upon historical data for 1983-85 (12, 13, 14).

Samples for Inhalable Particulate were found to range between 14 to 97 $\mu g/m^3$ during smoke events. No standards have been promulgated in Canada for this parameter. However, new standards published by the Environmental Protection Agency in the United States (15) have set a 24 hour primary standard for respirable particulate (10 micron cutoff size) of 150 $\mu g/m^3$.

The ratio of inhalable particulate to total particulate has been used as a means of determining the relationships between these

two methods of sampling, to allow historical data to be interpreted, and as a quality control check for particulate loading. The mean ratio of IH/TSP loadings during the study was 0.52, and is similar to data obtained at the downtown NAPS site (65 Ellen St.) in Winnipeg (16, 17).

Monitoring for PAH indicated that low levels of 24 of the 27 compounds examined during this study were present on all five days when sampling was initiated. The levels were, in most cases, well below the detectable limits reported during PAH surveys conducted in 1984 and 1985 (18, 19), and may be considered near background concentrations. One incident, on October 14, 1987, was recorded when total PAH concentrations were 105 ng/m^3, present predominantly in the vapor phase of the sample (see Appendix C for particulate/vapor phase distributions) acenapthylene (25.94 ng/m^3), fluorene (9.04 ng/m^3), phenanthrene (17.91 ng/m^3), and 2-methyl fluorene (12.55 ng/m^3) were found in highest concentration on this date, with significantly elevated concentration of other PAH compounds, in comparison to background. Elevated PAH concentrations were also noted on the other three days when smoke incidents were monitored. No national or provincial ambient air quality standards have been promulgated for the PAH compounds examined in this study. The State of Michigan (20) has established an annual average environmental acceptability level for PAH (as benzo (a) pyrene) oF 0.3 ng/m^3, which is connsidered a guideline level for permit screening.

Monitoring for VOC compounds indicated the presence of all 55 compounds examined during the study. A number of these chemicals were found at very low concentrations, and may be considered near

TABLE 6
PROVINCE OF ONTARIO
24 HOUR GUIDELINES AND STANDARDS
($\mu g/m^3$)

BENZENE	3,300	
TOLUENE	2,000	Odour
ETHYLBENZENE	4,000	Odour (1 Hour)
m, p-XYLENE	2,300	Odour
STYRENE	400	Odour
CARBON TETRACHLORIDE	7,000	Odour
CHLOROFORM	500	
DICHLOROMETHANE	100,000	Odour
TETRACHLOROETHYLENE	4,000	
TRICHLOROETHYLENE	28,000	

TABLE 7
COMPARISON OF SELECTED VOC CONCENTRATIONS

Compound	Winnipeg mean ($\mu g/m^3$)	Toronto mean ($\mu g/m^3$)	Montreal mean ($\mu g/m^3$)
n-Nonane	1.0	3.5	1.4
Decane	2.4	5.3	1.9
2,4-Dimethyl Pentane	0.5	0.8	
1,3,5-Trimethylbenzene	1.7	2.1	1.1
1,4 Dichlorobenzene	0.4	0.4	0.3
Chloroform	0.4	0.3	0.2
1,1,1-Trichloroethane	3.1	4.5	2.4
Trichloroethylene	0.6	1.8	0.7
Tetrachloroethylene	1.1	2.5	1.9
Carbon Tetrachloride	1.5	1.1	1.1

background. Other compounds exhibited little variability in concentration throughout the study, with mean levels similar to those reported in other jurisdictions (8) (see Table 7). These compounds were mostly chlorinated hydrocarbons, and were not considered as products emitted from combustion processes.

Certain of the VOC compounds monitored were found to vary in concentration throughout the study. Elevated levels of a number of aromatic compounds were observed during smoke episodes, most notably on October 14, 1987, with benzene (16.19 $\mu g/m^3$), toluene (31.56 $\mu g/m^3$), m, p-xylene (35.88 $\mu g/m^3$), o-xylene (14.77 $\mu g/m^3$), and 1,2,4-trimethylbenzene (18.07 $\mu g/m^3$) all significantly above background concentrations. At the time of this incident, winds were from the northwest.

The monitoring site was located in a residential area, approximately 5 kilometres northwest of the nearest industrial park. Therefore, VOC influences from industrial point sources of emission should be negligible. It is unclear what contribution light duty vehicle (LDV) exhaust emissions would have to the observed results, as a number of well travelled routes are present at distances between 250 and 800 metres from the site, on the north, east, and south sides. Inventories performed in the Toronto area (21) have identified LDV emissions as the one of the largest sources of aromatic compounds. Background data, taken on a Monday showed the presence of low levels of aromatics, with similar meteorological conditions to those observed on Wednesday, October 14. No ambient monitoring has been performed in the Winnipeg area to determine the variability of ambient VOC emissions.

Air quality guidelines have not been established for most of the VOC compounds examined in this study. The Ontario Ministry of the Environment (22) has set 24 hour ambient standards for a number of organic compounds, based upon health and odour concerns respectively. The guidelines are all far above the levels observed during the monitoring period (see Table 6).

CONCLUSIONS

Due to the sporadic nature and finite number of smoke-in-air events that occur each year, only limited opportunity is available for sampling. A number of the severe incidents which were observed in 1987 occurred in August, before sampling equipment was available. Therefore, findings may be considered as preliminary in nature, and further monitoring should be undertaken at a future date to verify and complement results from this study.

Preliminary conclusions are as follows:

1) Elevated levels of both total and inhalable particulate were observed at the sampling site during known smoke events in the Winnipeg area. In one case, TSP levels were found to exceed the 24 hour Maximum Acceptable Level of 120 $\mu g/m^3$
2) Elevated levels of various polynuclear aromatic hydrocarbons were observed during survey monitoring, in comparison to background. Levels were observed during known incidents of agricultural burning in the vicinity of Winnipeg.
3) Elevated levels of a number of aromatic compounds were noted during the study, during known incidents of agricultural burning near Winnipeg. It is unclear whether these emissions may be attributed directly to smoke incidents, or whether other sources, such a light duty vehicle exhaust contribute to observed concentrations.

ACKNOWLEDGEMENTS

Appreciation is expressed for the equipment and analytical support provided by the Conservation and Protection Branch of Environment Canada.

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APPENDIX A

PROPERTIES AND STRUCTURES OF POLYNUCLEAR AROMATIC HYDROCARBONS

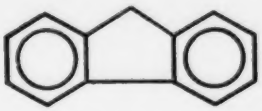
TABLE A1 - Properties of PAH
Commontly measured in Ambient Air

COMPOUND	MOLECULAR FORMULA	MOLECULAR WEIGHT
ACENAPHTHYLENE	$C_{12}H_8$	152.2
ACENAPHTHENE	$C_{12}H_{10}$	154.2
FLUORENE	$C_{13}H_{10}$	166.2
PHENANTHRENE	$C_{14}H_{10}$	178.2
ANTRACENE	$C_{14}H_{10}$	178.2
2-METHYL FLUORENE	$C_{14}H_{12}$	180.2
FLUORANTHENE	$C_{16}H_{10}$	202.3
PYRENE	$C_{16}H_{10}$	202.3
BENZO(a)FLUORENE	$C_{17}H_{12}$	216.3
BENZO(b)FLUORENE	$C_{17}H_{12}$	216.3
3-METHYL-PYRENE	$C_{17}H_{12}$	216.3
BENZO(g,h,i)FLUORANTHENE	$C_{18}H_{10}$	226.3
BENZO(a)ANTHRACENE	$C_{18}H_{12}$	228.3
CHRYSENE	$C_{18}H_{12}$	228.3
TRIPHENYLENE	$C_{18}H_{12}$	228.3
2-METHYL-BENZO(a)ANTHRACENE	$C_{19}H_{14}$	242.3
BENZO(b)FLUORANTHENE	$C_{20}H_{12}$	252.3
BENZO(k)FLUORANTHENE	$C_{20}H_{12}$	252.3
BENZO(e)PYRENE	$C_{20}H_{12}$	252.3
BENZO(a)PYRENE	$C_{20}H_{12}$	252.3
PERYLENE	$C_{20}H_{12}$	252.3
2-METHYL-CHOLANTHRENE	$C_{21}H_{16}$	268.4
DIBENZO-(a,c)&(a,h)ANTHRACENE	$C_{22}H_{14}$	278.4
BENZO(b)CHRYSENE	$C_{22}H_{14}$	278.4
BENZO(g,h,i)PERYLENE	$C_{22}H_{12}$	276.3
ANTHANTHRENE	$C_{22}H_{12}$	276.3

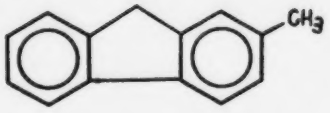
Figure A1: Structures of selected Polynuclear Aromatic Hydrocarbons

ACENAPHTHYLENE

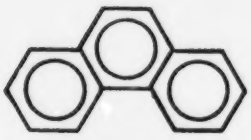
ACENAPHTHENE



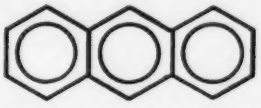
FLUORENE



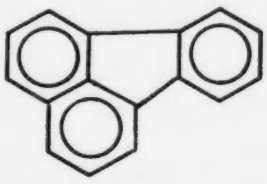
2-METHYL FLUORENE



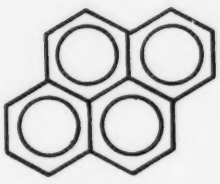
PHENANTHRENE



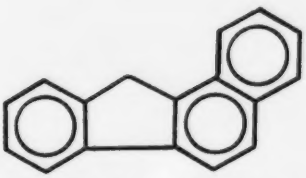
ANTHRACENE



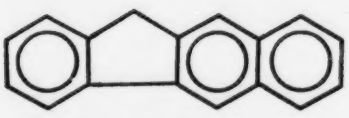
FLUORANTHENE



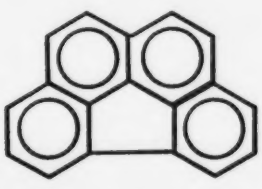
PYRENE



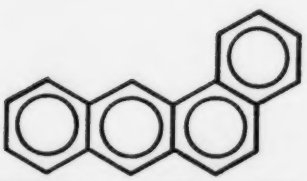
BENZO(a)FLUORENE



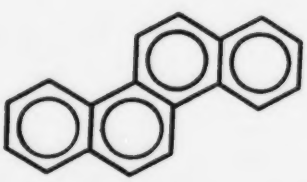
BENZO(b)FLUORENE



BENZO(g,h,i)FLUORANTHENE



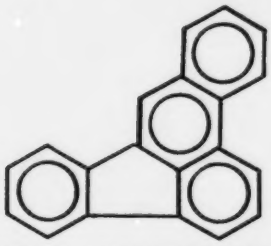
BENZO(a)ANTHRACENE



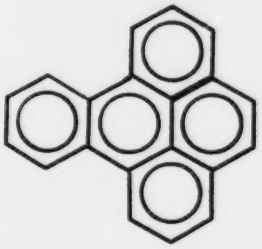
CHRYSENE

TRIPHENYLENE

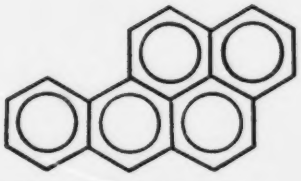
Figure A1: Structures of selected Polynuclear Aromatic Hydrocarbons (cont'd)



BENZO(b) FLUORANTHENE

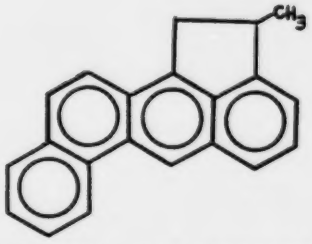


BENZO(e) PYRENE

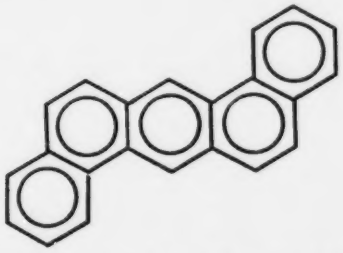


BENZO(a) PYRENE

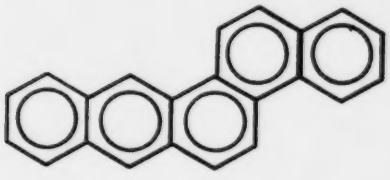
PERYLENE



2-METHYL-CHOLANTHRENE

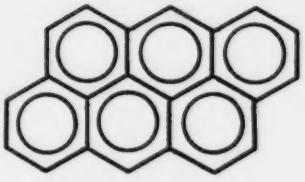


DIBENZO-(a,h) ANTHRACENE



BENZO(b) CHRYSENE

BENZO(g,h,i) PERYLENE



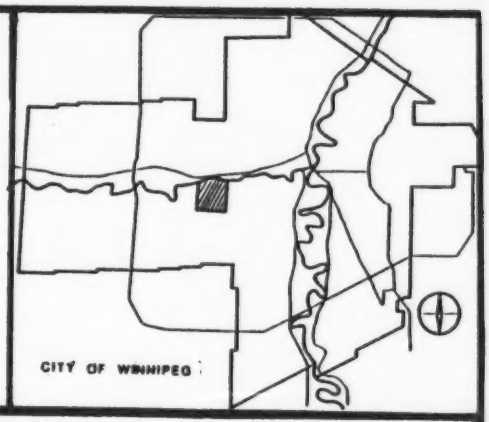
ANTHANTHRENE

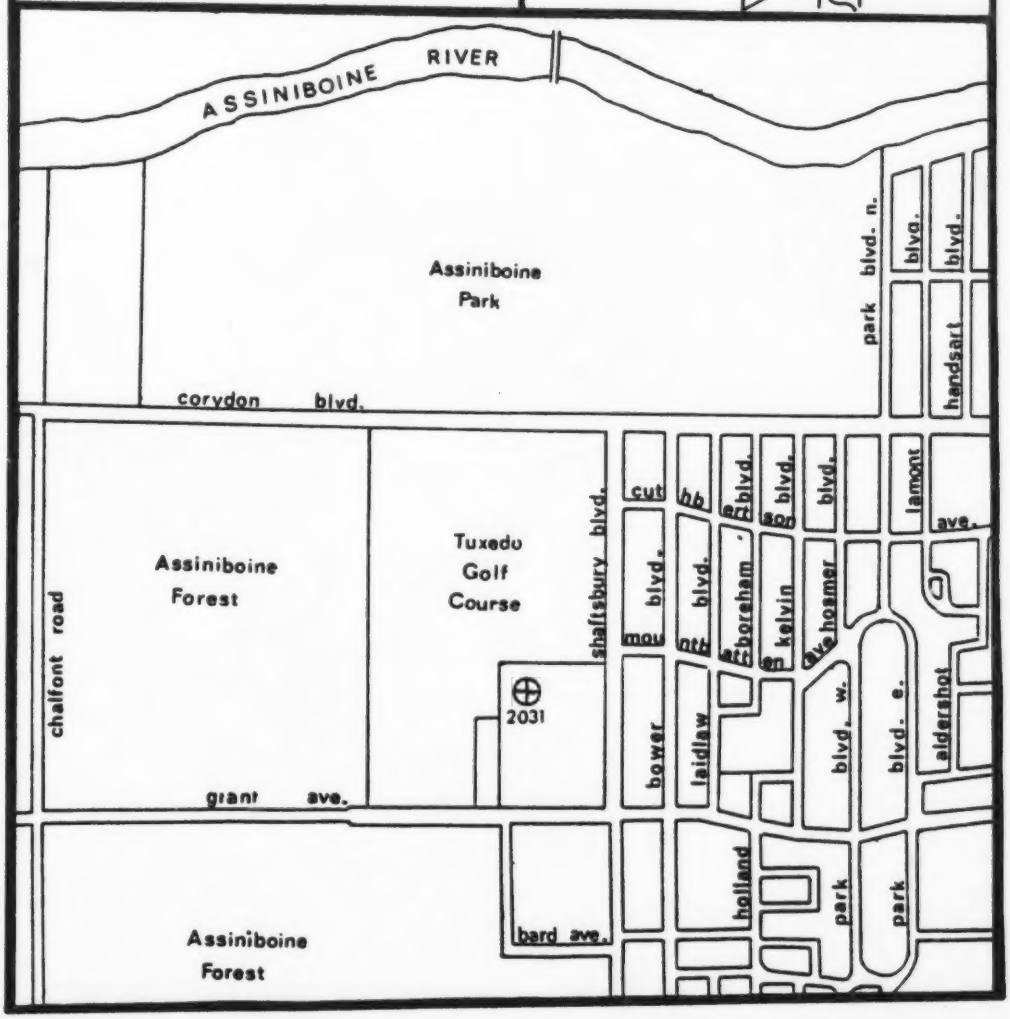
APPENDIX B

SITE MAPS

Map 1

Winnipeg
Monitoring Site 2031





APPENDIX C

Winnipeg PAH Concentrations (ng/m³)

	13-Sep-87 FILTER	13-Sep-87 T/B PUF	21-Sep-87 FILTER	21-Sep-87 T/B PUF	28-Sep-87 FILTER	28-Sep-87 T/B PUF	14-Oct-87 FILTER
Acenaphthylene		0.71		1.72		0.82	0.01
Acenaphthene		0.44		0.77		0.24	
Fluorene	0.01	2.27		3.97		1.14	0.01
2-Me-Fluorene		4.49	0.03	6.07	0.02	1.96	0.04
Phenanthrene	0.14	12.23	0.12	7.23	0.05	4.17	0.26
Anthracene	0.01	2.03		0.22		0.67	0.06
Fluoranthene	0.11	2.15	0.11	1.22	0.05	0.92	0.80
Pyrene	0.11	1.84	0.11	1.08	0.06	0.88	1.07
Benzo(a)Fluorene	0.07	0.35		0.22		0.20	0.54
Benzo(b)Fluorene	0.04	0.18		0.14		0.11	0.39
3-Me-Pyrene	0.05	0.18	0.05	0.11	0.02	0.09	0.37
Benzo(g,h,i)Fluoranthene	0.05	0.23	0.08	0.14	0.03	0.11	1.80
Benzo(a)Anthracene	0.22	0.10	0.06	0.05	0.06	0.04	1.40
Chrysene&Triphenylene	0.10	0.10	0.12	0.08	0.14	0.08	1.75
2-Me-Benzo(a)Anthracene							0.02
Benzo(b)Fluoranthene	0.57	0.04	0.71		0.33		3.93
Benzo(k)Fluoranthene							
Benzo(e)Pyrene	0.20		0.23		0.13		1.45
Benzo(a)Pyrene	0.10		0.09		0.06		1.31
Perylene	0.01						0.18
Me-Cholanthrene							
O-Phenylene	0.30		0.31		0.12		1.90
Dibenzo(a,c)&(a,h)Anthracene	0.03		0.03		0.02		0.16
Benzo(b)Chrysene							0.09
Benzo(g,h,i)Perylene	0.34		0.32		0.15		3.13
Anthanthrene							
TOTAL PAH	2.46	27.32	2.38	23.01	1.23	11.41	20.67
RECOVERY (%)							
*Acenapthene	39	70	29	87	36	84	22
*Anthracene	71	84	67	91	69	99	66
*Pyrene	97	88	87	97	95	104	92
*B(a)A	100	87	88	96	97	107	99
*B(a)P	93	82	82	93	90	97	94
*D(ah)A	102	86	91	103	102	109	112
*B(ghi)P	97	85	85	98	98	107	98
Perf. STD	100	91	95	96	100	107	97
SAMPLE VOLUME (m3)	735	735	647	647	1036	1036	895
TSP (µg/m³)	62.2		42.5		12.5		57.9
Sample ID	WIN-1	WIN-2	WIN-3	WIN-4	WIN-5	WIN-6	WIN-7

	14-Oct-87 T/B PUF	22-Oct-87 FILTER	22-Oct-87 T/B PUF
Acenaphthylene	25.93		2.97
Acenaphthene	3.79		0.69
Fluorene	9.03		3.08
2-Me-Fluorene	12.51	0.02	4.56
Phenanthrene	17.65	0.12	8.16
Anthracene	4.75	0.02	1.24
Fluoranthene	4.30	0.14	1.89
Pyrene	4.66	0.15	1.80
Benzo(a)Fluorene	0.63	0.06	0.26
Benzo(b)Fluorene	0.44	0.03	0.14
3-Me-Pyrene	0.27	0.05	0.11
Benzo(g,h,i)Fluoranthene	0.28	0.12	0.21
Benzo(a)Anthracene	0.07	0.12	0.02
Chrysene&Triphenylene	0.06	0.23	0.06
2-Me-Benzo(a)Anthracene			
Benzo(b)Fluoranthene		0.43	
Benzo(k)Fluoranthene		0.23	
Benzo(e)Pyrene		0.29	
Benzo(a)Pyrene		0.14	
Perylene		0.02	
Me-Cholanthrene			
O-Phenylene		0.43	
Dibenzo(a,c)&(a,h)Anthracene		0.03	
Benzo(b)Chrysene		0.02	
Benzo(g,h,i)Perylene		0.53	
Anthanthrene			
TOTAL PAH	84.36	3.16	25.19
RECOVERY (%)			
*Acenapthene	155	27	88
*Anthracene	88	67	84
*Pyrene	91	90	88
*B(a)A	92	95	84
*B(a)P	88	92	78
*D(ah)A	98	105	77
*B(ghi)P	94	99	78
Perl. STD	85	93	94
SAMPLE VOLUME (m3)	895	1014	1014
TSP (µg/m³)		30.0	
Sample ID	WIN-8	WIN-9	WIN-10